Decision on Run II Detector Upgrades

M. Witherell

September 3, 2003

Run II

Run II is the most important physics program operating currently in particle physics, since it is the only program with sufficient energy available to address many of the central scientific questions. We need to do as much science as possible with the CDF and D0 experiments in each and every year from now until the end of Run II. A major discovery of such important new physics as supersymmetry or extra dimensions would clearly reshape our understanding of particle physics. Evidence for or against the existence of a low-mass Higgs will also be very important. Run II will greatly improve our understanding of top quark physics, electroweak physics, heavy quark physics, QCD, and Higgs physics.

The laboratory's goal is to achieve the greatest sensitivity possible to discoveries of new physics, and to do so as quickly as possible. To achieve this goal will require delivering the most integrated luminosity throughout Run II while keeping the detectors operating as efficiently as possible for the most important physics.

Funding outlook

The strategy for pursuing physics in Run II depends on the funding available to carry it out. The funding for Fermilab and High Energy Physics in recent years has not kept up with the real effects of inflation. Since research at Fermilab is dominated by projects and programs committed to five years ago or more, the budget shortfalls have had a very large impact on the rest of the laboratory effort. This follows a larger pattern of funding for the Office of Science at the Department of Energy and for physical sciences across the board. After years of this funding trend, even the highest priority programs are not escaping the negative effects.

As a result of this trend, despite the acknowledged importance of the Run II program, we have been unable to secure a funding level for the laboratory that keeps up with inflation. Since FY 2001 we have diverted resources from everything else in the laboratory to ramp up the Run II effort, but such redirection cannot provide significant additional help in the future. The only programs that receive more than about 2% of Fermilab research funding are Run II, the neutrino program, and the LHC program, which together get about 87% of the total.

At the start of FY 2003, I announced to the laboratory a series of steps to accommodate the effects of the President's budget request of $286.3 million, effectively the same amount as was available in FY 2002. This involved redirecting about $15 million from the rest of the laboratory research program to increase the support for the accelerator effort and, to a lesser extent, for CDF and D0. In addition we took actions to reduce costs, including the introduction of an early retirement plan, a reduction of vacation accrual, travel reductions, and a freeze on most hiring. These steps made it possible to complete the scheduled accelerator work this year, but at great cost to the program. At this point we have no effective room for additional budget cuts without directly affecting Run II.

This year, Congress passed the final FY 2003 Fermilab budget at an additional $1.5 million below the budget request. More importantly, the FY 2004 budget request for Fermilab was announced to be $288.5 million, at about the same level as in FY 2002. This represents a

reduction of about $20 million in annual budget, correcting for real inflation, over two years. It is also several million dollars less than what we believed to be a minimum expectation.

We should be increasing the spending on Run II, including accelerator and detector efforts, by a total of about $20 million in FY 2004 relative to FY 2003. With the allotted budget, even though Run II was given the highest priority in assigning budgets, we fell about $6 million short of the amount needed. In addition, we have no reserve to deal with unforeseen new demands on the budget, or a general reduction in the laboratory budget like those we have had in recent years. Finally, we need to make up the shortfall created by a general reduction in this year's budget made well into the fiscal year.

In this budget environment, we must decide how to advance the Run II effort within the available resources, without unrealistic hopes for budgetary help from outside. We have looked at what we need to do within the context of limited resources and have tried to understand those components of our Run II program that are highest in priority and must be done and those that we can forego to make sure we complete the others.

We see three categories:

Must be done in order to operate the Run II program with high efficiency

1. accelerator operations
2. increased resources to improve accelerator performance immediately
3. detector operations
4. computing for analysis

Essential to reach the scientific goals of the luminosity upgrades to the accelerator

1. luminosity upgrades as specified in plan
2. additional accelerator personnel needed to complete those upgrades
3. non-silicon detector upgrades needed to keep pace with the luminosity
4. basic investment in accelerator infrastructure and maintenance to make sure the complex operates for collider and neutrino programs reliably through the decade

Important but not as essential as the items above

1. silicon upgrades to the detectors to ensure that the detectors maintain full efficiency to the end of Run II, even under pessimistic assumptions for lifetimes of the present detectors and optimistic assumptions for delivered luminosity
2. additional investment in accelerator infrastructure and maintenance
3. reserve to deal with new problems as they arise

Although we should be supporting all of these activities to exploit fully the scientific opportunities, we do not have the funds to do so. As a result, I have to make difficult decisions about the strategy for optimizing Run II science.

The detector upgrades

In developing this strategy, I have reviewed the scope of the detector upgrade projects. The nonsilicon upgrades for CDF and D0 are necessary for successful operation of the detectors throughout Run II, and we will complete them on the original project schedule. The much more

difficult issue is whether to proceed with the silicon upgrades in light of two important new pieces of information: the budget outlook described above and the detailed accelerator plan.

The accelerator upgrade plan document completed in June 2003 represents the first detailed plan for the entire period of Run II, based on bottoms-up technical plans and a detailed analysis of resources and schedule. It presents parameters supported by detailed modeling of the Tevatron and the antiproton cooling and accumulation systems. The experience acquired during two years of operation has given us a much better understanding of the accelerators, allowing us to benchmark the model we are now using as a planning tool. We are also better able to estimate the number of hours of accelerator operation we can normally expect to achieve each week. The resulting targets for Tevatron luminosity are lower than in previous estimates; they are also more realistic, since they are based on more complete information.

The scientific opportunity increases greatly with each factor of 2 in integrated luminosity recorded by the detectors. By the time the FY 2003 operation ends, the integrated luminosity delivered to each detector will be about 240 pb^{-1}. This corresponds to twice the data sample delivered in Run I. The luminosity upgrade plan gives estimates for integrated luminosity through the end of FY 2009 of 8.4 fb^{-1} in the design projection and 4.3 fb^{-1} in the base projection, corresponding to factors of 60 or 30 times Run I, respectively. Great physics will come from the large increase in data.

A year ago, without a fully detailed plan for the luminosity upgrade program, the best estimates of the integrated luminosity showed it surpassing 4 fb^{-1} around the end of FY 2006 and reaching the range 8 to 14 fb^{-1} by the end of FY 2009. This corresponded to operating with degraded silicon detectors for about three years and for up to 70% of the total integrated luminosity in Run II. In the most optimistic projections for luminosity, a second layer of silicon would be lost before the end of the run. Because much of the physics program requires tagging b jets, we planned to replace the silicon detectors to maintain excellent b-tagging efficiency. The PAC advised us that the detector upgrades should include full replacement of the silicon trackers, and we agreed.

With our present understanding of the expected luminosity performance, we project the integrated luminosity to reach 4 fb^{-1} around early FY 2008, assuming design performance. Assuming excellent execution of the ambitious accelerator plan, and full funding for that plan, the integrated luminosity through all of Run II will fall between the base and design projections. There is an irreducible uncertainty in estimating the luminosity achievable several years in advance when applying new techniques to the only antiproton-proton collider in the world. There is also significant unavoidable schedule uncertainty inherent in such a challenging upgrade program.

At the June 2003 meeting we asked the Physics Advisory Committee to consider the silicon detector upgrades. They used a simple model to study the possible outcomes for integrated luminosity times double b-tag efficiency. The physics sample defined in this way is significantly smaller at the end of FY 2007 than it would be without the detector installation shutdown required to install upgraded silicon detectors and the associated period for commissioning them.

The b-tagged physics sample for CDF in the scenario with upgraded silicon recovers from this deficit and does not quite reach the break-even point by the end of Run II, even in the design

projection. The existing CDF silicon detector should be able to operate at nearly full efficiency into FY 2008 in the design projection, even making pessimistic assumptions about silicon lifetime. After that it loses partial efficiency for b-tagging. If one makes more optimistic assumptions for the silicon loss, the existing CDF detector could operate well to the end of Run II. In the base luminosity projection, CDF does better with the existing detector under all assumptions about silicon lifetimes.

For D0, the comparisons are less optimistic and less certain. In the design projection, assuming the present shutdown schedule, the doubly b-tagged sample at D0 shows improvement some time in FY 2008 in the design projection, later in the base. These gains are partly due to the fact that the design of the D0 upgrade detector appears to give superior performance to that of the present detector, even without taking radiation damage into account. The D0 collaboration believes that they could reduce significantly the integrated luminosity lost due to silicon installation and commissioning from the present schedule, if a longer CDF installation did not have to be accommodated. We have not had the chance to review the newly proposed schedule in the way that would be needed to build it into the project.

The silicon detector teams in each collaboration have planned the upgrade project well and have made excellent progress. They deserve great credit for their rapid progress to date. The fast start on these projects demonstrates once again the excellence of the SiDet facility and the people who work there. In addition, the progress on developing the new readout chip, the SVX4, has been impressive. The present reconsideration of the silicon detector upgrade plan is motivated by the above considerations and not at all by any difficulties in the project execution.

Decision on the silicon detector upgrades

I have been considering this difficult issue for a few months, with input from not only the Physics Advisory Committee but also from a a large part of the Fermilab community. I have spent a great deal of time in trying to understand every ramification of what is a very important decision. I have decided that we will not include the silicon detectors in the continuing detector upgrade projects. I have made this decision in order to optimize the science we can achieve in Run II by concentrating our available resources on the accelerator upgrades and the other parts of the detector upgrades.

We have considered the possibility of upgrading the D0 detector alone, because of the additional benefits of replacing their current detector. Although the D0 physics sample might be increased somewhat in this case by the end of Run II, the CDF physics sample would probably suffer somewhat from the installation and commissioning of the D0 detector. The combined physics sample would be at best slightly larger, and could be comparable. The net gain to the total Run II science program would not be as great as the benefit of pushing the full list of accelerator improvements as quickly as possible.

Finally, I reaffirm the laboratory's strong commitment to Run II. This decision does not represent less commitment, but rather an attempt to ensure that we get the most science done with the real resources available. We have reorganized the accelerator effort to improve delivery of luminosity in the short term, and the new team is working well. We will now have the resources necessary to make immediate luminosity improvements, execute the luminosity upgrade program, make improvements to reliability, and hire additional accelerator physicists to

fill specific outstanding needs. We will be able to do this accelerator work without delaying items for budget reasons and still have the modicum of budget flexibility needed to overcome unexpected problems with the Run II effort. Finally, we will support rapid completion of the nonsilicon parts of the detector upgrades.

I have made this decision with the goal of optimizing Fermilab's physics program over the rest of this decade. Although the detector upgrades have been a topic of discussion for P5 and HEPAP, this was a decision for Fermilab to make. I paid careful attention to the arguments of the CDF and D0 collaborations and the oral discussion and written report of the Fermilab PAC, as I always do, but the responsibility for this decision rests with me. This decision should not be misinterpreted as a sign of lessening the intensity of focus on Run II. On the contrary, I have confidence in our ability to get the most integrated luminosity possible out of the accelerator complex and to do great physics with it.

Strategy and prospects for Run II

The strategy to pursue this exciting physics in Run II will be:

- to understand the factors that limit the present luminosity and act to resolve them,
- to address maintenance items and increase reliability of the complex,
- to pursue the ambitious upgrade program, including electon cooling in the Recycler, and
- to carry out the non-silicon upgrades that are needed for the CDF and D0 detectors to operate at higher luminosity.

We will increase luminosity as quickly as possible and will continue to focus the entire laboratory on the success of Run II.

The data sample will double to about 0.5 fb^{-1} in about one year and reach 1 fb^{-1} a year or so after that. By the end of Run II we will have delivered data samples to the detectors that are a factor of 30-60 times than that of Run I. Each detector is more capable than either of those used for Run I, even accounting for possible degradation in silicon detectors late in Run II, and the energy is somewhat higher, giving a large bonus for the most important physics studies. The prospects for discovery in Run II will remain brighter than anywhere else in particle physics until the LHC produces major new results.

Funding prospects

Many have expressed the concern that if we discontinue the silicon detector upgrades, even if we take this step as part of a responsible approach to optimizing the science return on Run II, it will have serious negative consequences for the Fermilab program and for high energy physics. They expect the modest funding saved by this step to be moved to other needs rather than for optimizing the accelerator effort at Fermilab. Indeed, some worry that it will open the way to further cuts that endanger Run II and accelerator operations at Fermilab.

I do not appropriate the Fermilab budget, so neither I nor anybody in our field can guarantee what will happen to our budget in the future. As Laboratory Director, what I can do is to direct the resources that are at my disposal in the way that produces the best science program. It would be a mistake for me to proceed on any other basis than scientific priorities and sound management.

Every major advisory committee in our field that has studied the cost and scientific benefit of Run II has rated it as the highest priority for particle physics. That list includes HEPAP subpanels, HEPAP, a National Academy study, and our own distinguished Physics Advisory Committee. I assume that P5 will come to the same conclusion. To further reduce Fermilab funding would have devastating effects on the science prospects for U.S. HEP over the next six years and beyond. I do not think that the reaction to responsible management of the Fermilab program would be to damage the scientific program with additional budget cuts. We must assume that the relevant government agencies will support particle physics in the most effective way possible with the resources available. That means sustaining support for Run II.

Addendum: Physics of Run II

As an addendum to this document I would like to call attention to the compelling summary of the exciting physics of Run II in the report of the Fermilab PAC meeting from June 2000.
You can find the relevant excerpt of the report here:
http://www.fnal.gov/directorate/program_planning/phys_adv_com/Physics_RunIIExcerpt.pdf .